Performance of an Accelerometer-Based Wireless Body Area Network in Indoor Environment: A Preliminary Study

P. Puspitaningayu[1,*], N. Funabiki[1], R.W. Sudibyo[2], H. Briantoro[2], Nurhayati[1] , T. Wrahatnolo[1]

[1] *Department of Electrical Engineering Universitas Negeri Surabaya, Indonesia*
[2] *Department of Information and Communication Engineering Okayama University, Japan*
[*] *Corresponding author. Email: pradinip@unesa.ac.id*

ABSTRACT

The promising purpose of wireless body area networks have brought a new paradigm in many aspects such as healthcare, lifestyle, and entertainment. One of the most popular sensors is the accelerometer which meant to monitor movements of its user. With the help of MEMS technology, an integrated chip which has both sensor and wireless module makes an easy way to monitor things. This paper provided a preliminary study on the performance of an accelerometer tag which works under the IEEE 802.15.4 standards with 2.45 GHz of frequency. The study included observing the behavior of the tag in indoor environment as it was strapped on the user's wrist while standing still or moving. The experiment showed that the accelerometer tag's RSS did not significantly affected by the user's movement by only 1.61% of difference. However, its packet loss was quite affected by the movements as it gets 43% worse than when it was not moving. Overall, the distance between the transmitter and the receiver was getting farther, the packet rate was also decreasing as a result of its dropping received signal strength.

Keywords: *WBAN, accelerometer, indoor, received signal strength, packet rate*

1. INTRODUCTION

Wireless Body Area Network (WBAN) is one of the most promising areas of wireless sensor networks which requires a low-cost, low-power, and consists of a set of sensors and a radio module used for communication [1]. WBAN itself is specifically attached on, worn, or even implanted inside human body to measure several vital parameters [2]. It is standardized under the IEEE 802.15.6 and the radio communication standard is closely related to the IEEE 802.15.4 for low-rate wireless personal area networks [3].

Moreover, with the support of MEMS technology, which opens up an integration between sensors, microcontroller, and wireless connectivity, research in WBAN gets more and more popular. Performance in WBANs are mainly focused on its protocol design related to power management, security, and the data quality which can be affected by distance, movements, or other wireless networks [4].

Meanwhile, as it is widely used in WSNs, accelerometer also plays an important role in WBANs as well since movement can be one of the major health parameters. As human walks, run, swing arms, or even blink can determine the health. Thus, research in motion sensing using accelerometers were already developed such as in posture recognition [5], heart monitoring [6], arm motion sensing [7], or various of movement disorders. The vast implementation of this sensor opens up major opportunities for WBAN. Figure 1 illustrates of the contribution of accelerometers to the technology.

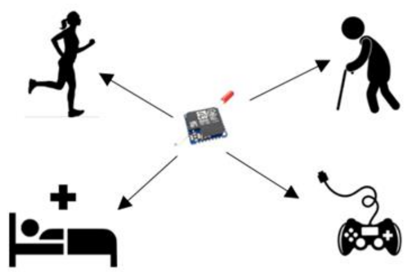

Figure 1 Examples of accelerometer use in WBAN

However, most research in evaluating the performance of WBANs during movement is performed were mostly conducted in simulation and theoretical terms such as in [8] [9] and [10]. Thus, considering its opportunities, this paper presented a preliminary study on the performance of an accelerometer tag works in 2.45 GHz in indoor environment by evaluating its real measurement data. By studying its performance, this paper objected to understand the behaviour of wireless accelerometer tag so it could be used for further movement monitoring in body area network research.

The paper was organized as follows: in section II the measurement procedures of the research was presented. The measurement scenarios were in section III. Finally, section IV and V provided results and conclusion respectively.

2. METHOD

2.1. Measurement Procedures

2.2.1. Indoor setting

The measurements were conducted in indoor environment at Okayama University Engineering Building 2 at the 3rd floor. There were some concrete wall and partition in the building. For this preliminary study, this paper did not differ the attenuation factor between each room. The measurements were focused on the performance of a wireless tag as transmitter and a USB stick connected to a PC as receiver. The picture below was the indoor layout used for the measurements.

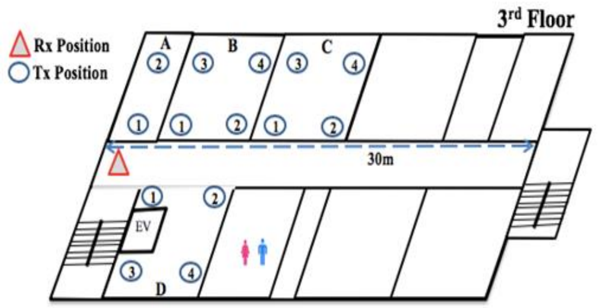

Figure 2 Indoor setting at Okayama University

The sensor was strapped using a velcro band to the user's right wrist who stood on each location from room A to D. Therefore, the measurement had 14 spots. The measurement also included several arm movements scenarios: stand still, raising the arms up, swinging, and twisting.

2.2.2. Hardware setting

The measurement was conducted to understand the behavior of the accelerometer tag in indoor setting and whether the user is moving or not. The device itself had a total of 16 channels available ranged from channel 11 to 26 with channel 15 as the default set up. The setup was done by adjusting its parameter on the server, then upload it by place the transmitter close to the USB receiver while unplugging and plugging the tag's battery. Below is the configuration of the hardware needed for the experiment.

Figure 3 Hardware Configuration

After upload process succeeded, monitoring the result after a setup was conducted by activating the sensor and its transmitter, the server displays each parameter while doing a set of serial transmission in close range.

The accelerometer tag was set to have this value:

Table 1. Wireless Accelerometer Setting

Channel	15
Tx power	3 dBm
Option bit	0・00000001
Sleep duration	50 ms
Sensor parameter	0

2.2. Measurement Scenarios

The first parameter measured was its link quality indicator (LQI). This value indicated the quality of the communication channel and its signal reception. Then, from the LQI, received signal strength can be calculated using a formula which is provided in datasheet:

$$RSS(dBm) = {(7LQI - 1970)}/{20} \quad (1)$$

Next, the measured parameter was received signal strength (RSS) of the wireless tag, received packet, and packet rate. Those four parameters were determined by the tag's quality measured by the receiver during experiments in below scenarios:

1. The user stood still while wearing the accelerometer tag from room A to D from one point to another as the map in Figure 2.
2. The receiver read data from the tag in one specific spot as it shown as the red triangle in Figure 2.
3. Then, the user moved as stated in section two and repeated all processes conducted in 1 and 2.

4. During experiments, the collection of data was performed in 60 seconds of interval to get the average value of received packet rate.

These are list of movements that was performed during the experiment:

Table 2. List of Movements During Experiments

Name	Initial Pose	Movement	Period
Move 1	Standing tall with straight arms beside the body	Moving the arms up and down	One cycle of breath each, repeat for 60 secs
Move 2	Standing with arms bent from the elbows beside the body	Swing the arms like its movement when running.	One cycle of breath each, repeat for 60 secs
Move 3	Standing with arms bent in front of the chest	Twist the body to the right and left.	One cycle of breath each, repeat for 60 secs

3. RESULT AND DISCUSSION

During measurements, there were two parameters which could be obtained automatically for each step namely the link quality indicator and the received packets. LQI itself was defined as the quality of the received signal computed either using the ED, the signal to noise ratio, or both [11]. From the LQI, using the formula presented in the previous section, the received signal strength (RSS) could be calculated. Therefore, the performance of its signal quality could be monitored and reviewed. Below are the table and graphs for LQI and RSS.

Table 3. LQI Measurement Results

Room	Static	Move-1	Move-2	Move-3
A1	97.8997	92.154	93.1533	84.242
A2	61.5894	71.5158	76.6547	63.5292
B1	83.14	73.826	76.6333	69.538
B2	27.988	45.5946	46.8913	47.0777
B3	78.3662	68.1447	58.0177	58.5778
B4	44.3004	49.0899	47.4419	45.6037
C1	45.89035	49.80508	44.85425	43.80702
C2	58.01277	44.43103	38.52532	35.56281
C3	49.08904	41.23029	31.75641	34.38327
C4	38.59684	39.11682	32.31138	38.64677
D1	85.57468	88.1335	72.19789	81.65378
D2	51.93402	52.13333	47.31012	52.25363

From the table above, LQI could be presented as graph which shown in Figure 4. The LQI itself did not have a unit; however, it clearly indicated that the one with higher LQI value had better quality.

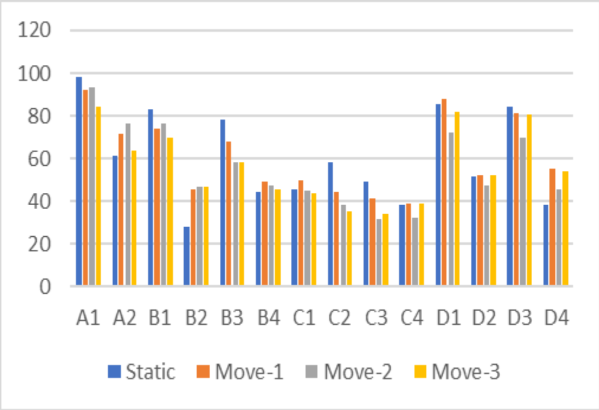

Figure 4 LQI values comparison

In addition, the LQI values could be converted to RSS in dBm unit by using the previous equation. The data were presented in both table 3 and figure 5.

Table 4. Received Signal Strength (DBM)

Room	Static	Move-1	Move-2	Move-3
A1	-64.2351	-66.2461	-65.8963	-69.0153
A2	-76.9437	-73.4695	-71.6709	-76.2648
B1	-69.401	-72.6609	-71.6783	-74.1617
B2	-88.7042	-82.5419	-82.088	-82.0228
B3	-71.0718	-74.6494	-78.1938	-77.9978
B4	-82.9949	-81.3185	-81.8953	-82.5387
C1	-82.4384	-81.0682	-82.801	-83.1675
C2	-78.1955	-82.9491	-85.0161	-86.053
C3	-81.3188	-84.0694	-87.3853	-86.4659
C4	-84.9911	-84.8091	-87.191	-84.9736
D1	-68.5489	-67.6533	-73.2307	-69.9212
D2	-80.3231	-80.2533	-81.9415	-80.2112

Overall, it could be seen that the closer the user to the receiver, the better LQI/RSS obtained. It also could be assumed that the wall between rooms affected its performance too, however the calculation for the attenuation factor had not been included in this preliminary study. Figure 5 presented the graph for RSS comparison for each movement in every room.

Table 5. Packet Rate (Packet/Second)

Room	Static	Move-1	Move-2	Move-3
A1	20.16	19.8	19.8833	19.4166
A2	19.95	18.55	19.0666	17.6666
B1	17.6166	18.7833	19.3166	18.4
B2	20	13.0333	13.35	13.5

B3	14.1167	18.4166	16.9	16.3833
B4	19.9333	14.6333	13.35	13.1666
C1	16.3	13.76667	12.35	11.4
C2	13.9833	11.6	10.53333	9.95
C3	18.2666	10.78333	7.8	8.566667
C4	14.6	10.7	8.35	10.05
D1	12.65	19.85	18.95	18.96667
D2	19.75	14.25	12.68333	14.91667

From the graph, it could be calculated that the average RSS when the device stayed still and when it was moved were -77.43 and -78.7 dBm respectively. This comparison showed that regardless the user stood still or moved the tag, the performance should be similar, thus tag was reliable to use for monitoring movement. There was only a slight difference in the RSS whether it was worn still or move.

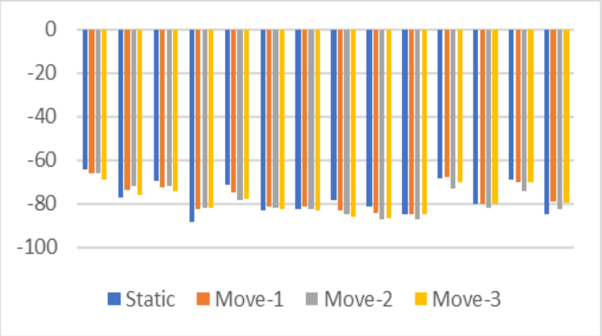

Figure 5 RSS value comparison

Finally, the last parameter to be considered was the average packet rate and packet loss for each position and movement. It was analyzed by counting the received packet shown at serial port data and divided by 60 as the measurement was conducted in one minute. Table III and figure 6 below are the packet rate performance shown in the measurement.

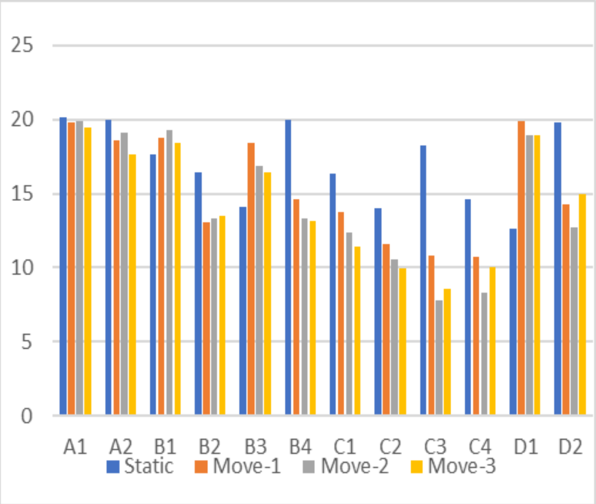

Figure 6 Packet rates comparison

From what is shown by both the table and the graph, packet rates varied as the distance increased. When the user stood still, the average packet rate was 16.98 packet/second. Since the expected packet retrieved should be 20, it also could be said that the average packet loss was15.1%. Meanwhile as it was moved, the average packet rate was 14.7 p/s and the packet loss was 26.5%.

4. CONCLUSION

From the experiments explained in the previous section, it could be concluded that the indoor performance of the wireless accelerometer tag did not significantly affected by the user's movement in terms of its received signal strength. The receiver was able to retrieve the signal regardless of user's movement.

However, for the packet rate performance, the received data when the user stood still was bigger by 13%. It resulted in increase of packet loss when the device moved was bigger than when it was in stood still position.

Above all, in general, its performance was strongly affected by distance and obstacles such as concrete walls as it was measured in several rooms of indoor setting. The received signal strength dropped when the user was far from the receiver point. With the RSS was decreasing, the packet rate was also dropped.

Further study will observe more about the behavior of the sensor, include the attenuation factor of the environment, and formulating the optimum setting for its application. By understanding its behavior, the implementation can be more precise and achieve optimum result in movement monitoring.

ACKNOWLEDGMENTS

This study was supported by Okayama University and Universitas Negeri Surabaya.

REFERENCES

[1] I Tomic, et all. "A Survey of Potential Security Issues in Existing Wireless Sensor Network Protocols". IEEE Internet of Things Journal, 2017.

[2] H Cao, et all. "Enabling technologies for wireless body area networks: A survey and outlook". IEEE Communication Magazine, 2009.

[3] R Cavallari, et all. "A Survey on Wireless Body Area Networks: Technologies and Design Challenges". IEEE Communications Surveys & Tutorials, 2014.

[4] B Johny & A Anpalagan. "Body Area Sensor Networks: Requirements, Operations, and Challenges". IEEE Potentials, 2014.

[5] E Farella, et all. “A Wireless Body Area Sensor Network for Posture Detection”. International Symposium on Computers and Communications, 2006, pp 454-459.

[6] E Kantoch, et all. “Wireless body area network system based on ECG and accelerometer pattern”. Computing in Cardiology, 2011, pp 245-248

[7] P Puspitaningayu, et all. “The Development of Wireless Body Area Network for Motion Sensing Application”. IOP Conference series: Material Science and Engineering 336, 2018.

[8] T Aoyagi & J Takada. “Body Motion and Channel Response of Dynamic Body Area Channel”. 6th European Conference on Antennas and Propagation (EUCAP), 2011

[9] JY Khan et all. “Wireless Body Area Network (WBAN) Design Techniques and Performance Evaluation”. Journal of Medical System, June 2012, Vol 36, Issue 3, pp 1441-1457.

[10] PT Hiep et all. “Performance Analysis of Multiple-hop Wireless Body Area Network”. Journal of Communications and Networks, vol. 17, No. 4, 2015.

[11] L Tang et all, “Channel Characterization and Link Quality Assessment of IEEE 802.15.4 Compliant Radio for Factory Environments”. IEEE Transactions on Industrial Informatics, Vol: 3, Issue 2, May 2007.